Multi-state Occupancy Example

Our modeling approach deals with both detection probabilities <1 and uncertainty in state classification. We then use the approach with occupancy and reproductive rate data from California spotted owls (*Strix occidentalis occidentalis*) collected in the central Sierra Nevada during the breeding season of 2004 to illustrate the utility of the modeling approach.

General Sampling Situation

The true states of the sites are

- unoccupied (state = 0),
- occupied with no production of young (state = 1), and
- occupied with successful reproduction (state = 2)

At each visit to a site, the result of the site visit is classified as

- no detection of the species (denote as 0),
- detection of the species in state 2, with no uncertainty associated with state assignment, or
- detection of the species with uncertain state assignment (denote as 1).

California Spotted Owl Reproduction: Data

We apply the above model to data from daytime visits to California spotted owl territories during April through mid-August of 2004 at the Eldorado study area in the central Sierra Nevada. Information about spotted owl population dynamics and sampling protocols at this study area can be found in Seamans et al. (2001) and Franklin et al. (2004). Visits to territories include efforts to locate adult owls. Once located, an owl is offered a live mouse and then visually followed after the mouse is taken. Definitive evidence of reproductive activity is provided when owls take mice to the nest or to young, and young are observed. Nonreproducing owls usually eat or cache mice, but such behavior at a single visit may not be indicative of a failure to reproduce. Investigators thus develop classification criteria to conclude whether an owl reproduces successfully or not

Detection histories are shown in the electronic appendix. Owls were detected at 47 of the 54 sites yielding a naïve occupancy probability of $\tilde{\psi}^1 \approx 0.87$. Young (successful reproduction) were detected at least once at 19 of the 47 sites known to be occupied, yielding a naïve reproductive estimate of $\tilde{\psi}^2 \approx 0.40$. The naïve estimate for overall probability of successful reproduction for a site was $\tilde{\psi}^{1*2} = \tilde{\psi}^1\tilde{\psi}^2 = 0.35$.

California Spotted Owl Reproduction: Models and Estimation

Classification parameters were modeled as constant over all time periods ($\delta_{it} = \delta$), as 1 parameter for periods 1-2 and another parameter for periods 3-5 ($\delta_{it} = \delta_{1-2}, \delta_{3-5}$; denoted as δ_2 for model designation), and as 5 time-specific parameters ($\delta_{it} = \delta_t$). The rationale underlying the δ_2 model concerned the time-dependence of reproduction, and the likelihood that successful reproduction would be impossible or very difficult to detect in the early portion of the breeding season, but much more readily detected later.

California Spotted Owl Reproduction: Results

The deviance based estimate of the variance inflation factor used in quasilikelihood adjustments was $\hat{c} = 1.28$, indicating reasonable fit of the most general model ($\psi^1, \psi^2, p_t^s, \delta_t$).

Exercise: fit the model, ψ^1,ψ^2,p,δ_2 and compare the naïve estimate of reproductive success (0.33) vs. the estimate from the model which accounts for imperfect detection and state uncertainty. Note: the 'δ_2' means the classification rate is constant for the 1st two surveys and constant but different for the last 3 surveys.